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Metal Forming Operations for the Process Engineer

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Metal Forming Operations for the Process Engineer

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1.0 INTRODUCTION

As the lead process engineer in a chemical plant the following problems have come across your desk.

1. Your company needs to install a storage tank in an area with limited space. All of your searching has not turned up a flat top and bottom storage tank with the dimensions you need to hold the chemical and still fit into the space. Your boss has told you to get a tank built. Where do you go to get this non standard odd dimensioned tank?

2. Your plant produces an unusual plastic product through an extrusion process using a very old piece of equipment. The main tube for the equipment has finally eroded to the point that the product is no longer of acceptable quality. This tube is three feet long with an original 2.75 inch inside diameter and a 6.25 inch outside diameter, one end has an external square thread with 1.5 threads per inch of length, the face of the other end is drilled for a 1.5” 600# flange. These dimensions do not match any standard stainless steel products, how do you obtain this critical piece to repair the equipment?

3. The grain chute feeding from the rail car dumping station into the grain storage conveyor needs to be replaced. The piece is square and has inside dimensions of 16.5 inches by 16.5 inches and is made up of four sections 10 feet long each, the wall is ¼ inch thick. You need to find a shop that can fabricate a new chute, your plan includes visiting several local shops. What pieces of equipment do they need to have to build a new chute?

4. The R&D Department has determined from reaction kinetics that the optimum dimensions for a reactor for their new product is 33.5 inches inside diameter by 48 inches on the straight side. Because of the pressure this needs to be an ASME code pressure vessel. All of your reference books indicate that standard ASME head diameters of 30”, 32” and 36” are the nearest you can come to the desired diameter. How do you solve this problem?

5. The existing exhaust stack off of an ore roasting oven needs to be redirected to allow for some structural reinforcement to the building housing the roaster. The existing stack goes straight up from the roaster and is 46 inches in inside diameter and is fabricated from 0.375 inch carbon steel sheet. The new route requires two 27 degree elbows. None of your local pipe or ductwork suppliers can supply the needed elbows. How do you obtain these parts?

2.0 GENERAL

In most chemical plants the Process Engineers are generally educated as Chemical Engineers, few of these receive any education in metal working. However the educational system views the chemical engineer the career eventually presents him / her with problems similar to the above.

Standard metal shapes are generally pipe, fittings, tubing, structural shapes and standard sized commodity tankage. The petroleum industry has generated a wide range of standard tank designs from the 300 gallon oval home heating oil tank to what were originally buried gasoline tanks in the 4,000, 6,000 and 10,000 gallon and larger sizes. Additionally much larger tanks, in the 1,000,000 gallon range, are available as field assembled units. Certain unusual tank shapes, spherical and hemispherical, are also available for specific needs such as large volume pressure storage tanks (spherical) and overhead water tanks (hemispherical). New environmental laws have almost eliminated the buried tanks and replaced them with above ground and double wall vessels; these are still "standard" sizes.

Obtaining these standard tanks and vessels requires minimal engineering effort from the process engineer. The same is true for pipes, valves and fittings. But engineering is not always satisfied with "standard" shapes and sizes and additionally the engineer frequently needs an unusual alloy formed or shaped to standard shapes.

The intent of this material is to introduce the Process Engineer to the various metal forming operations available for his / her use. The intent is not to train Process Engineers in metal working but to provide sufficient information to allow for a better decision making process around the metal working processes to be used to form new equipment, repair existing units or build new facility components.

3.0 METAL FORMING OPTIONS

Metal forming is achieved on a variety of machines most of which can perform more than one metal forming operation. Let's look at the various machines capable of creating round holes in metal, in this case we are only considering equipment we would expect to find in a local metal working shop.

Precision holes

- Punch Press
- Drill Press
- Milling Machine
- Lathe
- CO_2 laser "torch"

Approximate sized holes

- Oxygen fuel gas torch (oxy-acetylene, oxy-hydrogen, etc.)
- High pressure water / mineral grit jet

Plasma arc torch

When having an item fabricated the engineer needs to be aware of the tolerance requirements for the part. For example assume you need to cut a clearance hole in a 0.25 inch floor plate for a 2 inch sch 40 pipe. The pipe has a 2.375 inch outside diameter so a 3.25 inch hole is workable. It is also possible to get by with a 3.0 inch hole and even a 3.5 inch hole. There is little reason to pay extra for a drilled pipe clearance hole in this piece of floor plate when a torch cut hole can easily meet the tolerance of 0.5 inches on the diameter.

When a specific metal forming operation is required it pays to discuss the need with the shop foreman in the forming shop; many years of experience have taught him / her the least expensive, most accurate and most efficient approach to developing specific metal shapes.

For example a conical bottom for a hopper can be formed by either of the following methods. Refer to ATTACHMENT 1, “Metal Pattern for Frustum of a Cone” for the proper shape of metal and the end result of the two processes.

- Rolling a properly cut metal section in a plate roll
- Make multiple small bends on a properly shaped piece of metal using a press break.

A rolled cone will have a smoothly curved surface except at the weld joint whereas the press break produced cone will actually consist of a series of small flat triangles. The press break cone may be less expensive to produce than the rolled cone but that depends on the normal methods used by the fabricator.

So not only tolerance needs to be considered but the final appearance is important. In the above example of the cone the two forming methods both produce the proper shape and to the required dimensions; in the plate rolled cone the final appearance is slightly better looking but offers no significant advantages beyond that.

4.0 DEFINITIONS

We need to establish some common term definitions in order to understand what happens to metal in the various forming processes. First off “forming” has a specific meaning in some shops, we’ll use it to mean any activity which changes the shape of metal in any manner.

Standard metal shapes from which most specialized shapes begin include the following:

Sheet & Plate	Usually 4’x 8’, 5’x 10’, 4’x 10’, 6’x 10’, 4’x 20’, etc. sheet sizes ranging in thickness from 44 gage (0.0047”) to multiple inches
Rolls (Coils)	Usually up to 3/8” thick and of varying length depending on gage
Structural shapes	Angles, channels, “I” beams, flat bar, square, round, hexagonal, octagonal, etc. bars,

Pipe	From 1/8” up
Tubing	Hollows in round, rectangular, square and octagonal shapes ranging in the major dimension from 1/16” (0.0625”) up
Threaded rod	Generally available from 1/8” up to several inches in diameter and in a variety of threads including US standard, SAE, metric and ACME configurations.

Most of the above shapes can be found in the common metal alloys including carbon steels, 300 and 400 series stainless steels, brass and copper, and various aluminum alloys. Some shapes are available in exotic alloys such as Hastelloy, monel, Carpenter 20, etc.

Some of these shapes can be formed by local metal forming shops. It is common to form short sections of angle, channel, and tees. Some care must be taken in this area since these formed structural pieces will probably not conform exactly to standard structural shapes so Moments of Inertia, Section Modulus and weight per unit length will require calculation.

5.0 BASIC METAL FORMING PROCESSES

Part of the reason for understanding metal forming operations is that on occasion the engineer needs special shapes in unusual metals and must be able to find the people to fabricate the part. To evaluate the possibility that a shop can provide the necessary metal forming means the engineer needs some basic knowledge of what metal forming operations are possible.

Metal can be shaped by a variety of means

Cutting to shape or size
Rolling or bending to shape
Removing material to form specific shapes
Adding pieces of metal together

Each of these operations is performed by a specific machine, generally the machine has multiple capabilities. For example most plate rolls can also roll wire and rod into circles.

BENDING Generally limited to angular shapes in flat bars and some simple structural shapes. For example if you needed a frame made of ¼” by 2” flat bar similar to Sample 1 then a bending tool followed by welding would be the simple way to fabricate the piece. Benders range in size from table top manual rigs to hydraulic powered units. These units in large sizes are sheet metal or press breaks.

BREAKING A metal forming technique where a blade is pressed onto metal secured over a “v” shaped die and which results in the metal sheet or shape being bent into an angle of the desired number of degrees. A variety of blade and die shapes are available. The metal’s yield strength must be exceeded to make a permanent change in shape, on some alloys the metal must be "over bent" because of the tendency of the material to spring back somewhat. The tool is generally available for sheet metal (sheet metal break) and as a separate machine for heavier metal (press break), see Sketches 1 and 2 for the tools operation and Sample 2 for a simple product of the tool. These tools range in the width of metal they will bend from 12 inches to slightly more than 10 feet.

BORING Generally this is lathe work using an adjustable tool to create cylindrical and tapered holes of any size or depth. In the case of the lathe the metal to be bored is rotated against the cutting tool. Examples of lathe work would be to bore a hole of a specific size in a piece of metal bar stock or turn a 3 inch round bar to an outside diameter of 2.65 inches. See Sketch 3 for the tool operation and Sample 3 for a sample product.

CASTING Most of today's engineers probably would not consider this as a viable metal forming process of interest. Indeed it is generally relegated to art works and manufactured items. When unusual shapes are required which would normally involved a lot of hand welding and grinding to fabricate then this versatile process should be considered. Wooden patterns are inexpensive to make and can be used for multiple pieces. Almost all metals can be cast with today's technology.

CUTTING Probably the most common method of changing the shape of metal. This process can employ a wide variety of forms, some examples of which are: oxygen acetylene, oxygen propane (or other fuel gas), water jet with mineral grit, oxygen lance (ferrous only), laser, saw blades, abrasive cut off wheels, hand shears, etc.

DRILLING The process of cutting circular holes in metal using drill bits or hole saws. The available range of holes produced is enormous, drills are available from several thousandths to several inches, hole saws increase the range up to about 6 inches in diameter. Where drills are capable of work in very thick metal the hole saws are generally limited to about 1.5" in thickness. Drills can cut "blind" holes (don't go through the metal) but hole saws need to penetrate the metal to produce a hole.

FORGING This is generally reserved for production of items such as tools, pipe fittings, and heavy shapes. Probably the original true metal forming operation and in the hands of a master blacksmith can form quite accurate and detailed shapes. This is not generally a process called on by the process engineer. Some standard forged shapes impacting the process engineer include valve bodies and pipe fittings.

GRINDING The process of removing metal using a high speed abrasive wheel (not a manual operation as in welding) which essentially duplicates the actions of the lathe, milling machine, planer or shaper and producing an extremely fine finish on the metal. Occasionally grinding follows lathe work to produce a specific surface finish.

MILLING The process of removing small amounts of metal using cutters of various shapes on a milling machine to produce flat spots, curves or other shapes. These machines range in size from tiny hobby units sitting on a table top to units capable of milling steam generating turbines. The process engineer rarely needs the larger size of these machines as his / her work is generally limited to making replacement parts or fabricating small specialized items. Milling machines cut slots in shafts for keys, slots for bolts for adjustable parts, splines and gears. See Attachment A.

NIBBLING A sheet metal cutting process during which small pieces of metal are punched out by a moving tooth to form a specific shape from the sheet. Manual nibblers can handle 0.25 inch thick metal.

PLANING This equipment is used to produce very flat surfaces on large metal sheets in a manner similar to planing a piece of wood. This is generally not a process needed by the process engineer except to fabricate equipment for the production of cast plastic sheets or pressure molded flat laminate sheets.

PUNCHING This is generally a process used to produce various shaped holes in sheets of metal using punches and dies. These holes are generally limited to standard punch and die sizes. Punches and dies must be selected to match the metal thickness. A range of hole shapes includes round, square, rectangular, oval and multiple sided.

ROLLING A “rolling mill” is one step in producing standard shapes of metal in a steel mill. This is also a technique of forming metal sheets into cylindrical or conical shapes and for shaping structural shapes into circles or portions of a circle. This is accomplished by passing the metal through three or more large (with respect to the metal thickness) diameter rollers in such a manner as to cause the metal to assume a cylindrical or conical shape. If the edge of a metal sheet enters the gap between the top and bottom rolls parallel to the length of the rolls the end result is a cylinder or flat circle, entry angles other than parallel produce sections of cones.
Structural shapes can be rolled in two directions, the “easy” way and the “hard” way. For example a ¼” by 2” flat bar can be rolled the easy way in which case the result is a flat hoop similar to what is used on wooden barrels. With difficulty the same flat bar can be rolled to produce a flat doughnut with the outside diameter 4 inches larger than the inside diameter. Each structural shape and alloy has a minimum circular radius it can assume by rolling without over stressing and cracking the material or

producing a wavy distorted shape caused by a buckling failure of the material.
The shape becomes permanent if the metal is stressed beyond its yield strength in the forming process. When the equipment is designed to roll sheets of metal it is usually called a “plate roll” and for structural shapes an “angle roll”. Sizes of equipment range from table top light gage rolls to massive hydraulic powered rolls capable of rolling multiple inch thick plate. See Sketch 4.

SHEARING A cutting operation which cuts sheets of metal or structural shapes using a powered machine operating in a fashion similar to a pair of scissors. The cutting blade descends in the same manner as the top blade of the scissors, contacting one edge of the sheet before the other edge. In most shears this means that the cutting action moves from one edge of the metal sheet to the opposite, it is not cut all at once regardless of the apparent speed. Shears rang in size from manual operated table top units to massive plate shears capable of cutting multiple inch thick plates. Most local shops will probably be limited to a ½” plate shear which generally means a 10 foot wide by ½” thick plate can be sheared in one motion. Smaller structural shears are designed to shear angles, tubing, flat bar and round bar in one relatively small machine; most metal forming shops will have an “Iron Workers” of this type. See Sketch 5.

SLITTING Essentially a cutting operation for use on long sheets of metal; for example if the metal shop has ¼” plate that is 4 feet wide and 20 feet long but needs strips 9.5” wide then the metal can be passed through a slitting saw lengthwise to produce the strips. Most local metal forming shops will not have slitting saws.

SHAPING Frequently the work required involves changing the shape of small metal pieces, the work may be accomplished using a milling machine, a shaper or a lathe depending on part size and the desired shape. Generally both a shaper and a milling machine rotate the cutting tool while a lathe rotates to part to be shaped.
This is generally a common tool in a true machine shop, less often found in sheet metal shops.

SPINNING A hot or cold metal forming operation used to produce shapes against a form or set of control rollers. Examples in the process industry are dished heads of varying thickness and diameters. Rarely a process found in local shops. See Sketch 6.

STAMPING This is generally a production process producing food cans, thin dished heads, light fixtures, and automobile sheet metal parts.

STRAIGHTENING The process of un-rolling coils of metal and producing flat sheets.

This is not a process normally called on by the process engineer but by the metal supplier.

SURFACE FINISHING This is a finishing process and doesn't usually affect the shape of the metal except on a microscopic level. Included are grinding, polishing, peening, sand blasting, bead blasting, etc. The purposes varies but is usually used to achieve a specific surface texture.

TURNING This was one of the early machine tool operations and is accomplished on a wide variety of lathes. The lathe operates by rotating the material to be shaped against a cutting tool, the cutting tool may move along the length of the metal being shaped, down the length of a hole being bored in the metal or across the face of the metal. Machines range in size from tiny watch makers lathes to units turning steam generator turbines. Lathes are rated by the diameter and length of parts which can be turned, for example a 10 inch by 36 inch lathe in most cases means a piece of metal 10 inches in diameter by 36 inches long can be turned to shape; size nomenclatures are not always consist manufacturer to manufacturer . See Sketch 3.

WELDING This is possibly the most common of metal working processes but is usually not listed as a metal forming process. It is placed here in that it can be and many times must be used to form the finished process equipment. For example a reactor vessel is fabricated in two steps; the first is a plate rolling operation to form the shell followed by welding of the vertical seam in the shell's cylinder. There are more than fifty (50) welding processes and perhaps eight to ten used frequently in the construction of process industry equipment. The reader will find several references to this process under References.

6.0 METAL FORMING SHOPS

Metal forming shops carry a variety of names depending on the part of the country you're in and the local industry they serve. Generally you can arrange for work in shops with the following designations:

XYZ Welding	XYZ (Textile, Paper, Mining, etc.) Machinery
XYZ Sheet Metal	XYZ Pressure Vessel Shop
XYZ Machine Shop	XYZ Tank Fabrication
XYZ Fabricators	

For example a well equipped tank fabrication shop will most likely be equipped with the following machines:

Plate roll	Cutting equipment
Lathe	Angle roll
Press break	Plate shear
Welding equipment	Drill press

Metal forming covers a very wide range of metal thickness, the range of thickness needed in most process industries varies from light gauge (26 gage) to relatively heavy walled materials as exemplified by schedule 160 pipe which exceeds 2 inches in thickness for a 24 inch pipe. Light gages, for example 26 gage (0.0187"), are generally reserved for ductwork for HVAC and dust collectors, weather covers and the like. Gages in the 11 gage (~1/8") to 3 gage (~1/4") are used for small tanks, flue gas stacks, abrasive materials conveying chutes and the like. Heavier plate is used for pressure vessels and portions of tall towers and flat ended pressure vessels (heat exchanger tube sheets for example).

Most local fabrication shops will probably be limited to 3/8" to ½" plate rolling capacity. In areas with heavy industry, iron and steel mills, petroleum refineries, ship building and the like local shops frequently have very heavy metal forming equipment.

Depending on the shop "sheet metal" ranges up to ¼" thick, above that thickness flat metal sheets are generally called plate.

7.0 FABRICATING A VESSEL

To get a better feel for the capability of the metal forming operations needed let's look at building a chemical reactor. See Attachment 5 for the shape of the vessel we want to build.

This reactor consists of the following parts:

1. 316 ss 96" outside diameter by 96" high cylindrical shell, 3/8" wall
2. 316 ss 96" F&D (Flanged & Dished) ASME heads (2), 3/8" thick
3. 304 ss 102" ID diameter jacket shell (~3" space), ¼" thick by 48" high and approximately 322.0 inches long.
4. 304 ss jacket seal rings (2), 3/8" thick with ID equal to 96.375" and OD equal to 102.375"
5. 304 ss pipe legs (4), 4 feet long, 6" schedule 80 pipe
6. 304 ss leg gussets, fabricated from ½" plate
7. 304 ss leg anchor plates, ½" thick by 12" by 12" with 4 holes punched ¾" diameter
8. Nozzles (4), 6" long 2" schedule 40 316 ss pipe with ANSI 150# RF flanges

Now we can look at each piece and determine how that part will be obtained for the fabrication of the reactor.

1. Reactor shell

   This part needs to be rolled from a 3/8" sheet of metal 8 feet high by approximately 300.4" long. The plate length is normally calculated based on the diameter at the center of the wall then adjusted for any weld preparation or gap required depending on the selected welding process. Once the cylinder is rolled then a code quality weld is made to finish the cylinder.

To complete the above tasks the shop needs:

a. Plate shear to cut the sheet to be rolled or to cut numerous smaller sheets to create the full size plate for the shell.
b. Equipment to weld the vertical seam in the vessel shell or multiple welds if the shell is rolled from multiple sheets.
c. Plate roll to form the reactor cylinder

2. F&D Heads

These are generally purchased by the fabricator unless the purchase order is with one of the larger pressure vessel fabricators who form the heads they use.

a. The shop will need a crane or large fork truck to move the heads into place and hold them for welding to the rolled shell.

3. Jacket Shell

To complete the above tasks the shop needs:

a. Plate shear to cut the sheet to be rolled or to cut numerous smaller sheets to create the full size plate for the shell. Plate size is 48 inches by ~320.0 inches
b. Equipment to weld the vertical seam in the jacket or multiple welds if the jacket is rolled from multiple sheets.
c. Plate roll to form the jacket cylinder
d. A crane to position the jacket for welding.

4. Jacket Seal Rings.

These flat rings seal the top and bottom of the jacket to the vessel shell.

To complete and install these parts the shop needs.

a. Circle cutting machine which can be a plasma torch on a radius arm or a mechanical cutting device. Since these rings are stainless steel an oxy-acteylene torch is not usable. The shape of these parts can either be full circles or parts of circles. Installation requires careful hand positioning and welding as required by the pressure design.

5. Vessel legs

These are cut from schedule 80 pipe.

To complete and install these parts the shop needs.

a. The shop needs to be able to cut pipe to the specified length with square cuts and prepare the ends for welding. This can be accomplished with a variety of saws and hand grinding or lathe work for end preparation.

6. Vessel Leg Gussets
These are cut from ½” 304 stainless steel plate.

To complete and install these parts the shop needs.

a. Because the metal is stainless torch cutting is either plasma or laser, oxy-acetylene is not usable. A variety of saws will also work, as will a plate shear.
b. The plates are assembled to the pipe legs by welding.

7. Vessel Leg Anchor plates
These are cut from ½” 304 stainless steel plate.

To complete and install these parts the shop needs.

a. Because the metal is stainless torch cutting is either plasma or laser, oxy-acetylene is not usable. A variety of saws will also work, as will a plate shear.
b. The plates require anchor bolt holes which can be drilled, punched or torch cut.

8. Pipe nozzles
These are generally purchased items.

a. The pipe nipples will need cutting from a longer pipe length and the ends prepared for welding to the purchased flanges, this requires a cut off saw, hand grinders or lathe.
b. Installation requires that holes be cut in curved surfaces of the vessel shell or heads using either a hole saw or careful torch work. Nozzles need to be installed either parallel to or perpendicular to the vessel vertical center line.

All of the above parts need to be assembled carefully which generally means the reactor needs to be supported in such a manner that allows the welders to use levels and squares to properly position other components for welding.

Once the vessel is complete then some testing is generally required. Although not metal forming equipment this test equipment is essential to completing the activity. Testing is usually limited to hydrostatic testing which means the vessel needs to sit upright and be filled with the proper kind of water. For example hydro testing on stainless steel vessels usually requires low chloride water and a method of building pressure on the filled vessel.

8.0 GENERAL GUIDELINES

Several general guidelines will assist in maximizing the potential and minimizing the cost of fabrication.

- Generally the more precision requested in a dimension the more costly it becomes. For example a flame cut hole usually costs less than the same size drilled hole.
- The tighter the tolerance applied to any dimension the more the cost. For example specifying a width of 4.255" costs more to fabricate than 4.3".
- Specifying non-standard holes costs more than standard holes. For example specifying a hole 0.255" in diameter means the hole probably will need to be reamed to final size as opposed to using an off the shelf drill bit.
- The finer the required surface finish the more expensive it becomes as it requires finer grit paper and more labor.
- Specifying items using all or most of a standard metal sheet size costs less. For example metal is generally available in 48", 60" and 72" widths. Producing a design calling for a 49 inch wide piece of metal probably cost more than the same design utilizing a 60 inch sheet since the shop has to cut the material and thus there is more labor involved.

9.0 ANSWERING THE INITIAL QUESTIONS

QUESTION 1

How do you obtain an odd shaped vessel with an unusual diameter?

ANSWER: Since you need a flat bottom and top this is most likely not a pressure rated vessel so a variety of shapes are available for use. The shell of the tank can be rolled from flat plate by almost any tank fabricator to whatever diameter is required. Unusual heights are accomplished by welding together multiple short rolled cylinders. The top and bottom flat heads can be cut from the appropriate size plate and welded to the cylinder. Some shops have the capability of forming oval cylinders, which would allow for the creation of a tall oval tank if necessary. Finally square or rectangular tanks are a common shape easily fabricated by most metal working shops.

QUESTION 2

How do you obtain a thick walled tube with odd OD and ID and non-standard external threads? SEE ATTACHMENT 2

ANSWER: SOLUTION 1

Starting from a solid piece of metal slightly large than the required final OD turn to final outside dimension on a lathe. Using a drill and boring bar on a lathe cut a hole the full length of the piece and finish to the desired ID using the boring bar. Cut the external threads on a threading lathe by adjusting the various gears to provide the correct pitch, the thread shape is usually controlled by the shape of the thread cutting tool. The end which mates to the pipe flange needs to be drilled and tapped on a drill press or perhaps a horizontal boring machine.

SOLUTION 2

Starting from a piece of tubing with a thicker than required wall turn to final outside dimension on a lathe. Using a boring bar enlarge the existing hole the full length of the piece and finish to the desired ID using the boring bar. Cut the external threads on a threading lathe by adjusting the various gears to provide the correct pitch, the thread shape is usually controlled by the shape of the thread cutting tool. The end which mates to the pipe flange needs to be drilled and tapped on a drill press or perhaps a horizontal boring machine.

QUESTION 3

How do you build a square tube 16.5" by 16.5" inside by 40 feet long? SEE ATTACHMENT 3

ANSWER The are several standard ways to form the square tubing:

- Press break two 90 degree sections 10 feet long and weld them together
- Press break a sheet into a 10 foot "U" shape and weld on one flat piece to form the tube
- Press break two 10 foot "U's" and weld them together to form the tube
- Shear four pieces (sides) 10 feet long of the tube and weld them to form the tube, two pieces to be 16.5" wide and two to be about 16", allowance needs to be made for the welds.

The last option is the most expensive since it requires four welds, the others are similar in cost; the second option is a little more difficult from a welding perspective.

QUESTION 4

How do we obtain a 33.5" ID reactor with ASME dished heads?

ANSWER: Some years ago dished heads were only available in specific sizes with increments of about 2 inches on the diameter. ASME dished heads are now usually available in almost any requested diameter from some of the larger manufacturers. An Internet search yields multiple "any" diameter offerings for ASME and other styles of heads.

QUESTION 5

Where do you obtain 27 degree 46 inch ID 0.375 inch wall flanged 1.5 r/D elbows? SEE ATTACHMENT 4

ANSWER: THE FABRICATION OF ODD DEGREE ELBOWS IS ACCOMPLISHED BY PATTERN DEVELOPMENT USING GEOMETRY AND DRAFTING TECHNIQUES. TODAY'S COMPUTER CAD SYSTEMS CAN GENERATE ACCURATE METAL PATTERNS QUICKLY AND ACCURATELY. FOR EXAMPLE THESE ODD ANGLE ELBOWS ARE CREATED BY ROLLING ELBOW SECTIONS CALLED "GORES" TO FORM PORTIONS OF THE ELBOW WHICH ARE THEN WELDED TOGETHER. SIMILAR PATTERN DEVELOPMENT IS USED TO PRODUCE ELBOWS, TEES, "Y"'S AND A VARIETY OR PIPE TO PIPE INTERSECTIONS. A REVIEW OF SHEET METAL PATTERN DEVELOPMENT BOOKS OFFERS THE ENGINEER A WIDE RANGE OF FABRICATION KNOWLEDGE.

10.0 REFERENCES

- "Welding Principles and Applications" Jeffus & Johnson, Delmar Publications, Inc.
- American Welding Society, Miami, Florida
- "Sheet Metal Patterns" Daughtery & Powell, Chas. A. Bennet Co.
- "Metalworking Handbook, Principles and Procedures" Adams, Arco Publishing, New York
- "Marks Mechanical Engineer's Handbook" McGraw Hill Book Company, New York

11.0 CONCLUSION

Being able to obtain equipment to exact calculated size for new equipment is increasingly important as quality and productivity requirements are tightened. Likewise the ability of the engineer to obtain replacement parts to increase the life of critical equipment is generally a worthwhile cost cutting effort.

The investment of a small amount of time looking at metal forming equipment and watching certain basic forming processes in action pays strong dividends in an engineer's career.

This personal educational effort is generally neglected by colleges but is easily obtained and enhances the engineer's capabilities and value to his / her employer.